[5] A plot of log log antheridial hyphae vs. log concentration of A^2 reveals a linear relationship. From this it follows that $I = e^{ax^k}$, where I is reaction intensity, x, the concentration of A^2 and k, a proportionality constant. The author wishes to thank Dr. Leonard J. Savage for pointing out this relationship.

[6] An alternate interpretation of A^2 activity might be that the water-soluble fraction of ♀ filtrate contains A^1 plus an effective contamination of A. The pattern of A^1 augmentation on A^2 response and the expected response curve of an $A + A^1$ mixture, when the two hormones are simultaneously diluted, lend strong support for such an hypothesis. On quantitative grounds, however, it is apparent that no possible mixture of hormones A and A^1 could give either the augmentative or inhibitory effects attributed to hormone A^2 when the water-soluble fraction is added to known concentrations of hormone A in the absence and presence of A^1, respectively (Figs. 3 and 4). It is because of these latter effects that the interpretation presented in this paper is favored over that of a mixture of previously known hormones.

ELECTRON TRANSFER IN INTERMETALLIC COMPOUNDS

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In our discussions of the electronic structure of intermetallic compounds during the last three years brief mention has been made from time to time of the phenomenon of electron transfer.[1-3] The interpretation of the observed interatomic distances in many metallic phases seems to require the assumption that electron transfer has taken place; an example is Al_9Co_2, for which the distances[4] support the charge distribution[5] $Al_9^{-2/9}Co_2^{+1}$. The indication by physical properties of a filled-Brillouin-zone structure for Fe_5Zn_{21} also led to the suggestion of electron transfer:[2] about $1/4$ electron is indicated to have been removed from each zinc atom and about one electron added to each iron atom.

In this paper it is pointed out that the analysis of interatomic distances shows that electron transfer takes place in a great many interatomic compounds, and that the numbers of electrons involved are reasonable, in relation to the changes in valence resulting from loss or gain of electrons and to the partial ionic character of the bonds between unlike atoms and the striving of atoms toward electroneutrality.

Let us divide atoms into three classes: hypoelectronic (electron-deficient) atoms, hyperelectronic (electron-excess) atoms, and buffer atoms. Hypoelectronic atoms are atoms that can increase their valence by adding electrons. The hypoelectronic elements include the first three elements of each short period and the first five elements of each long period, as shown in

table 1. Atoms of these elements have more bond orbitals than valence electrons (in the uncharged state), and they can accordingly increase their valence by one unit by accepting an electron. Hyperelectronic atoms are atoms that can increase their valence by giving up an electron. The hyperelectronic elements with respect to metallic compounds include the last three elements (before the noble gases) of each short period and the last seven elements of each long period. Atoms of these elements have more valence electrons than bond orbitals, and they can increase their valence by one unit by giving up one electron of a pair occupying a bond orbital, thus leaving a valence electron in the orbital. Buffer atoms are atoms that can give up or accept an electron without change in valence. The five elements Cr, Mn, Fe, Co, and Ni and their congeners in the other two long periods are buffer elements with respect to metallic compounds;

TABLE 1

CLASSIFICATION OF ATOMS WITH RESPECT TO EFFECT OF CHANGE OF ELECTRON NUMBER ON METALLIC VALENCE

HYPOELECTRONIC ATOMS					ATOMS WITH STABLE VALENCE					HYPERELECTRONIC ATOMS						
	Li	Be	B					C					N	O	F	
	Na	Mg	Al					Si					P	S	Cl	
					BUFFER ATOMS											
K	Ca	Sc	Ti	V	Cr[a]	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br
Rb	Sr	Y	Zr	Nb	Mo[a]	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
Cs	Ba	La	Ce[b]													
		Lu	Hf	Ta	W[a]	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At

[a] These three atoms can accept electrons but not give up electrons without change in valence.

[b] The rare-earth metals may have some buffering power.

they can give up a non-bonding *d* electron or introduce an electron into the incomplete non-bonding *d* subshell without change in metallic valence (Cr, Mo, and W are buffer atoms with respect only to addition of an electron).

Carbon and silicon are placed in a separate class in table 1. Carbon is an element with stable valence, 4; either the addition of an electron to a carbon atom or the removal of an electron from it causes a decrease in its valence. Silicon also has the stable valence 4, except that it may under certain circumstances make use of outer orbitals (3*d*, 4*s*, 4*p*) and achieve some increase in valence through electron transfer. This effect is less important in alloys of silicon than in compounds of the hypoelectronic atoms.

Let us consider the ways in which an intermetallic compound AB might be stabilized by the transfer of an electron from atom B to atom A.

First, an increase in the number of valence bonds and a corresponding increase in stability would result from electron transfer from B to A if A

were hypoelectronic and B were hyperelectronic, or if A were hypoelectronic and B were a buffer, or if A were a buffer and B were hyperelectronic.

Second, according to the principle of electroneutrality[6] an increase in stability would result from a transfer of electrons if it were to result in a decrease in the electric charges on the atoms. Let B be more electronegative than A. The covalent bonds between A and B would then have some ionic character, of such a nature as to give A a positive electric charge and B a negative charge. By transferring an electron from B to A the charges on the atoms can be reduced, and the substance can thus be stabilized. It is very interesting that this effect involves the transfer of electrons to the more electropositive atoms (the stronger metals); that is, in the opposite direction to that of the transfer of electrons that takes place in the formation of ions in electrolytic solutions.

These two stabilizing effects usually operate together, because the electronegativity increases in the sequence hypoelectronic elements, buffers, hyperelectronic elements. Both effects are stronger for compounds of hypoelectronic elements with hyperelectronic elements than for compounds of elements of either of these two classes with buffer elements. Thus we expect electron transfer to be especially important for compounds such as $NaZn_{13}$, less important for compounds such as Al_9Co_2 and Fe_5Zn_{21}, and of little significance for compounds such as Na_2K, FeCr, and Cu_5Zn_8.

In special cases electron transfer may take place even in compounds of two metals in the same class. Stabilizing factors that might operate to this end include the filling of Brillouin zones, the stabilizing of partially filled non-bonding subshells through increase in multiplicity (approach to half-filling) or through completion of the subshell, and the relief of strain resulting from geometric constraints on ratios of interatomic distances through change in bond numbers.

The compound AlP may be taken as a simple example. It has the sphalerite structure, in which each atom is surrounded tetrahedrally by four unlike atoms. Aluminum is a hypoelectronic atom, with normal valence 3 and with single-bond radius 1.248 Å. Phosphorus is a hyperelectronic atom, with normal valence 3 (resulting from occupancy of four orbitals by five electrons) and single-bond radius 1.10 Å. The predicted Al—P distance for valence 3 and bond number n equal to $^3/_4$ is $1.25 + 1.10 - 0.600 \log n = 2.43$ Å. The observed distance 2.35 Å., does not agree with this value, but is exactly equal to the sum of the single-bond radii; that is, the observed distance indicates that each atom forms four single bonds with its neighbors. We are thus led to describe the crystal by saying that it is composed of quadrivalent $\cdot\dot{A}l^{-}\cdot$ and $\cdot\dot{P}^{+}\cdot$, with formal charges -1 and $+1$, respectively; and that, because phosphorus is more electronegative than aluminum, each of the four single bonds formed by

each atom has about 25% ionic character, in such direction as to restore the transferred electrons from the aluminum atoms to the phosphorus atoms, achieving at the same time the extra stability that results from ionic-covalent bond resonance.

Comparison of observed and predicted interatomic distances for the thirty other tetrahedral compounds of this type shows that in general electron transfer occurs, with increase in valence of about one unit for each atom.

As another example we may discuss the striking purple alloy Al_2Au, which has the fluorite structure, with $a_0 = 5.99$ Å. Each gold atom has eight aluminum ligates, at 2.59 Å. If gold retained its usual metallic valence, $5^1/_2$, the eight Au—Al bonds would have bond number 11/16, and the corresponding correction $-0.600 \log n = 0.098$, plus the single-bond radii 1.338 for gold and 1.248 for aluminum, would give the predicted Au—Al distance 2.684 Å., which is so much greater than the observed value as to eliminate the assumed valences. Agreement is obtained by assuming gold to have the valence 7; the corresponding radius[3] is 1.303 Å., and the bond-number correction, for $n = 7/8$, is 0.035, leading to 2.586 Å. for Au—Al.

The valence 7 can be achieved by a neutral gold atom (without a metallic orbital). However, in order for gold to have valence 7, aluminum must have valence $3^1/_2$, or greater if significant Al—Al bonds are formed; and hence at least one electron per gold atom must have been transferred to the aluminum atoms. Indeed, the observed Al—Al distance 3.00 Å. for the six aluminum ligates about each aluminum atom corresponds to $n = 0.15$, and indicates that a significant amount of valence of the aluminum atoms is used in these bonds. It is likely that about 1.5 electrons are removed from each gold atom, which would liberate the customary 0.75 metallic orbital, the valence remaining 7; 0.75 electron added to each aluminum atom would increase the aluminum valence to 3.75, of which $3^1/_2$ would be used in bonds to the four gold ligates, and the remainder in Al—Al bonds.

This large amount of electron transfer is not incompatible with the electroneutrality principle. The electronegativity of aluminum is 1.5, and that of gold is 2.5. The difference corresponds to 22% ionic character of the Au—Al bonds, which with valence 7 for gold would lead to the charge -1.54 on the gold atom. To restore it to neutrality 1.54 electrons would have to be transferred to two aluminum atoms.

The proposed structure provides an explanation of the very high melting point (1060°C.) and large heat of formation of the compound.[7] Coffinberry and Hultgren[8] pointed out that the properties of the Al—Au alloys indicate the operation of an unusually strong attraction between aluminum atoms and gold atoms.

As an example of a compound in which electron transfer is relatively unimportant we may discuss $PtSn_2$, which also has the fluorite structure, a_0 being 6.41 Å. The normal metallic valences 6 for platinum and 4 for tin permit the formation of Pt—Sn bonds with $n = {}^2/_3$ and Sn—Sn bonds with $n = {}^1/_6$. The predicted Pt—Sn distance 1.295 + 1.399 + 0.106 = 2.800 Å. is only slightly high, the observed distance being 2.78 Å. The predicted Sn—Sn distance for $n = 1/6$, 3.27 Å., is also slightly higher than the observed value, 3.21 Å., and a small amount of electron transfer is accordingly indicated. The electronegativity values, 2.2 for platinum and 1.7 for tin, lead to about 6% ionic character of the bonds, and to charges on the atoms that would be neutralized by the transfer of 0.36 electron from each platinum atom to two tin atoms. The increase in valence of tin by 0.18 would increase n for the Sn—Sn bonds to 0.20, and would decrease the radius of tin[3] by 0.01 Å.; the predicted distances Pt—Al = 2.79 Å. and Al—Al = 3.20 Å. are in excellent agreement with the observed values.

Electron transfer is especially important in the alloys of the alkali and alkaline-earth metals with hyperelectronic elements and buffer elements. In the formation of many of these alloys from the elements a very large volume contraction is observed, resulting in part from the bond-number correction of interatomic distances due to the increase in valence, and in part from the decrease in single-bond radius of the hypoelectronic atom with increase in valence. Thus, although the normal radius of sodium for ligancy 12, 1.896 Å., is greater than that of lead, 1.746 Å., the replacement of one fourth of the lead atoms in pure lead by sodium atoms, to form the phase $NaPb_3$, leads to a contraction, the bond distance decreasing from 3.492 Å. to 3.446 Å. This decrease is explained by the assumption that electron transfer occurs, with a little less than one electron transferred to the sodium atom. For Na^-, with valence 2, the single-bond radius would be predicted to be 1.439 Å. (0.075 Å. greater than for Mg), which leads to Na—Pb = 3.413 Å., slightly less than the observed value, and the Pb—Pb distance is also predicted to be decreased by about the observed amount, as the result of the increase in valence of lead and in bond number of the Pb—Pb bonds. In many other intermetallic compounds of the alkali and alkaline-earth metals the interatomic distances similarly indicate that electron transfer occurs to such an extent as to increase the valence by about one unit.

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[1] Pauling, L., *J. Am. Chem. Soc.*, **69**, 542 (1947).
[2] Pauling, L., and Ewing, F. J., *Rev. Mod. Phys.*, **20**, 112 (1948).
[3] Pauling, L., *Proc. Roy. Soc.*, **A196**, 343 (1949).
[4] Douglas, A. M. B., *Acta Cryst.*, **3**, 19 (1950).

[5] Pauling, L., *Ibid.*, in press.

[6] Pauling, L., *Victor Henri Memorial Volume*, Liège, Maison Desser, 1948; *J. Chem. Soc.*, 1948, 1461.

[7] Roberts-Austen, W. C., *Proc. Roy. Soc.*, 49, 347 (1891); 50, 367 (1892).

[8] Coffinberry, A. S., and Hultgren, R., *Am. Inst. Min. and Met. Eng.*, Tech. Pub. No. 885, 1938.

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*IMMUNOGENETIC AND BIOCHEMICAL STUDIES OF NEUROSPORA CRASSA: DIFFERENCES IN TYROSINASE ACTIVITY BETWEEN MATING TYPES OF STRAIN 15300 (ALBINO-2)**

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The concept that primary gene action consists of the determination of protein specificities and that genes bear a one-to-one relation to such specificities rests largely on biochemical investigations utilizing Neurospora and immunogenetic investigations of vertebrate erythrocytic antigens.[1, 2] The fruitfulness of this hypothesis has been large, but questions have been raised as to the suitability of the methods and materials used in the above investigations.[3, 4] Accordingly we have recently initiated a series of studies utilizing a new approach.

The material chosen for this work has been the two mating types (*A* and *a*) of Strain 15300 (albino-2), *Neurospora crassa*.[5] Mating type, which may be regarded as a specificity difference rather than a true sexual difference, is determined by two alleles (*A* and *a*) at a locus on the opposite side of the centromere of chromosome I (linkage group *A*) from the locus of albino-2.[6] The object of these studies has been to demonstrate possible differences in antigenic specificity and enzymatic specificity attributable to the mating type locus in addition to the mating type difference.

The results of the antigenic analysis indicate clear-cut antigenic differences between the two mating types.[7] In the course of this work it was necessary to prepare homogenates of whole mycelia. These homogenates were prepared from mycelia of strains 15300*a* and 15300*A* cultured, without shaking, in 100-ml. portions of medium in 250-ml. Erlenmeyer flasks. The medium employed consisted of 5 g. of KH_2PO_4, 7 g. of Difco Yeast Extract and 50 g. of dextrose which were dissolved in distilled water and the volume made to one liter. The sterile medium was inoculated and the cultures were incubated at 30°C. for twelve or thirteen days, after which time the thick mycelial pads were removed by filtration, washed